# Recent top quark properties in CMS

PHENO 2020: 2020 Phenomenology Symposium

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on behalf of the CMS Collaboration

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# Top quark overview

## Main properties

- Heaviest particle of SM: $\frac{1}{2}$ spin, $\frac{2}{3}e$, color charge
- Participates to all interactions
- "Natural" mass:

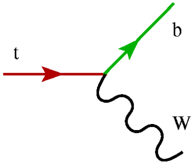
$$m_{\text{top}} = y_t \frac{v}{\sqrt{2}} \simeq 174\,\mathrm{GeV} \Longrightarrow y_t \sim 1$$

  - Privileged relationship with Higgs boson
  - Possible role in the EWSB mechanism

- Decay happens before hadronization can occur:

$$\tau_{top} = \frac{h}{\Gamma_{top}} \simeq \frac{h}{G_F\, m_{\text{top}}^3 |\mathrm{V_{tb}}| \frac{2}{8\pi\sqrt{2}}} \simeq 2 \times 10^{-25} s$$

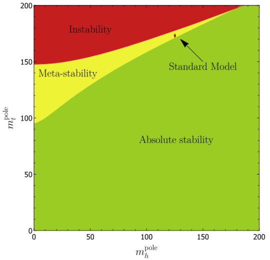
- Angular properties directly accessible through its decay products
- Weak interaction decay, dominantly in a W boson and a b quark



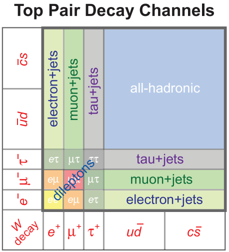
# Top quark mass

## Why is it important?

- Key input for EW precision tests
- Crucial interplay with the Higgs and $\alpha_S$
  - EW vacuum stability
- Cosmological consequences
- Challenging for experiments and theory
  - theory ambiguities on $\mathrm{m_t^{MC}}$ vs. $\mathrm{m_t^{pole}}$



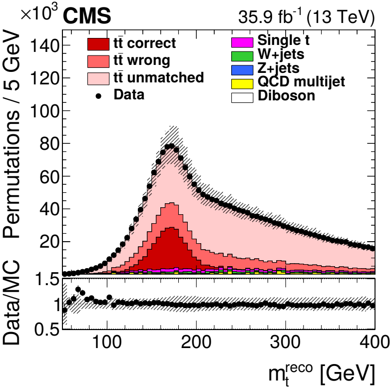

## How can it be determined?

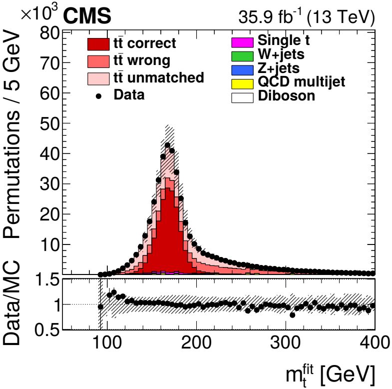



- Direct measurements:
  - observable dependent on $\mathrm{m_t}$
- Indirect measurements:
  - property $\mathrm{f(m_t^{pole})}$
- Many decay channels, many experimental observables $\rightarrow$ combination

# Direct top mass in $\ell$+jets final state

- 1 high-pt isolated e/$\mu$, $N_{jets} \geq 4$, $N_{b-tags} = 2$
- Reconstruction using $m_W$ constraint + kinematic fit $\rightarrow$ goodness of fit
- Ideogram method: joint likelihood for $m_t$ and $JSF$ to constraint JECs to reduce corresponding uncertainty




$$m_t = 172.25 \pm 0.08(\text{stat}) \pm 0.62(\text{syst}) \quad \epsilon_{m_t} = 3.6\ ‰$$

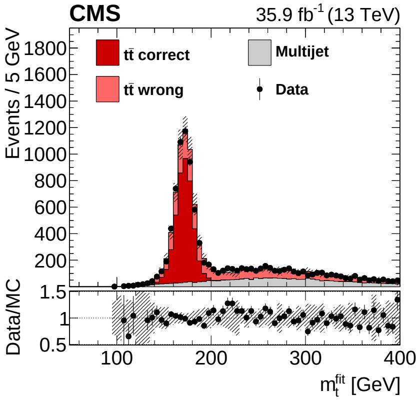
$$JSF = 0.996 \pm 0.001(\text{stat}) \pm 0.008(\text{syst})$$

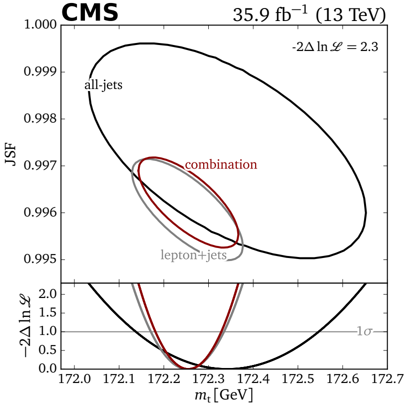
Eur. Phys. J. C 78 (2018) 891

# Direct top mass in all-had final state

- $N_{jets} = 6,\ N_{b-tags} = 2$
- Same strategy of $\ell$+jets analysis

Eur. Phys. J. C 79 (2019) 313




$m_t = 172.34 \pm 0.20(\text{stat}) \pm 0.70(\text{syst})$

$JSF = 0.997 \pm 0.002(\text{stat}) \pm 0.007(\text{syst})$

$m_t = 172.26 \pm 0.07(\text{stat}) \pm 0.61(\text{syst})$

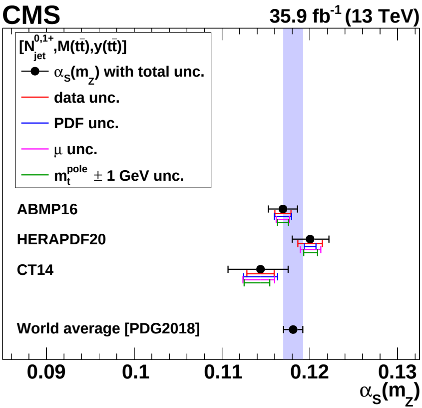
$JSF = 0.996 \pm 0.001(\text{stat}) \pm 0.007(\text{syst})$

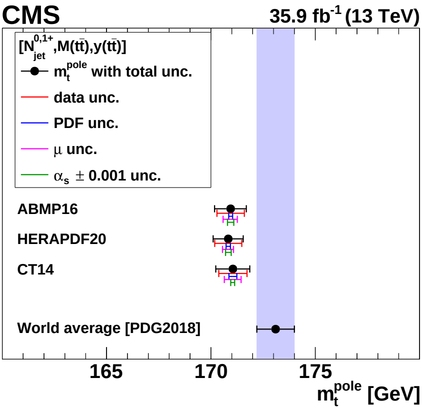
# Indirect top pole mass in dilepton final state

- Details on the analysis → see Silvano's talk
- Triple-differential $\sigma(N_{\mathrm{jets}}, m(t\bar{t}), y(t\bar{t}))$

arXiv:1904.05237

Submitted to JHEP




$$\alpha_S(m_Z) = 0.1135 \pm 0.0016(\mathrm{fit})^{+0.0002}_{-0.0004}(\mathrm{model})^{+0.0008}_{-0.0001}(\mathrm{param})^{+0.0011}_{-0.0005}(\mathrm{scale})$$

$$m_t^{\mathrm{pole}} = 170.5 \pm 0.7(\mathrm{fit}) \pm 0.1(\mathrm{model})^{+0.0}_{-0.1}(\mathrm{param}) \pm 0.3(\mathrm{scale})\ \mathrm{GeV}$$

# Direct top MC mass in dilepton final state

- Kinematic fit for full event reconstruction

Eur. Phys. J. C 79 (2019) 368

- $m_{\ell b}^{min}$ increases sensitivity to $m_{\mathrm{t}}$
- 12 regions in $N_{\mathrm{jets}}$ and $N_{\mathrm{b-jets}}$
- Simultaneous fit for cross section and mass extraction

$$\sigma_{\mathrm{t\bar{t}}} = 815 \pm 2\,(\mathrm{stat}) \pm 29\,(\mathrm{syst}) \pm 20\,(\mathrm{lumi})\,\mathrm{pb}$$
$$m_{\mathrm{t}}^{\mathrm{MC}} = 172.33 \pm 0.14\,(\mathrm{stat})\,^{+0.66}_{-0.72}\,(\mathrm{syst})\,\mathrm{GeV}$$

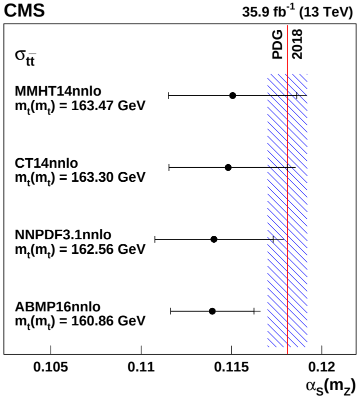
- Residual dependence of the cross section on $m_{\mathrm{t}}^{\mathrm{MC}}$
  $\rightarrow$ indirect measurement of $m_{\mathrm{t}}^{\mathrm{pole}}$

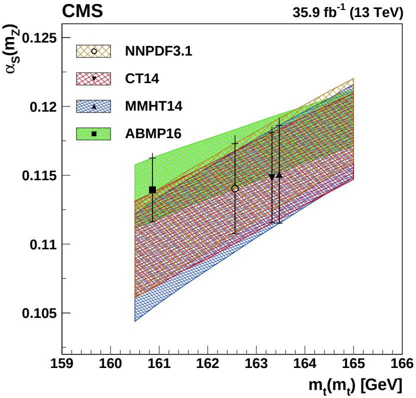
| PDF set | $m_{\mathrm{t}}^{\mathrm{pole}}$ [GeV] |
|---|---|
| ABMP16 | $169.9 \pm 1.8(\mathrm{fit} + \mathrm{PDF} + \alpha_S)^{+0.8}_{-1.2}(\mathrm{scale})$ |
| NNPDF3.1 | $173.2 \pm 1.9(\mathrm{fit} + \mathrm{PDF} + \alpha_S)^{+0.9}_{-1.3}(\mathrm{scale})$ |
| CT14 | $173.7 \pm 2.0(\mathrm{fit} + \mathrm{PDF} + \alpha_S)^{+0.9}_{-1.4}(\mathrm{scale})$ |
| MMHT14 | $173.6 \pm 1.9(\mathrm{fit} + \mathrm{PDF} + \alpha_S)^{+0.9}_{-1.4}(\mathrm{scale})$ |

# Indirect $\overline{\mathrm{MS}}$ top mass in dilepton final state

$$\sigma_{t\bar{t}} = 815 \pm 2\,(\text{stat}) \pm 29\,(\text{syst}) \pm 20\,(\text{lumi})\ \text{pb}$$
$$m_t^{MC} = 172.33 \pm 0.14\,(\text{stat})\ ^{+0.66}_{-0.72}\,(\text{syst})\ \text{GeV}$$

- Residual dependence of the cross section on $m_t^{MC}$
  $\rightarrow$ indirect $m_t(m_t)$ and $\alpha_S$ determination: Eur. Phys. J. C 79 (2019) 368



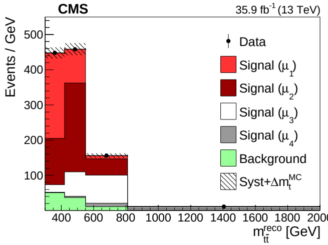
# Running top mass

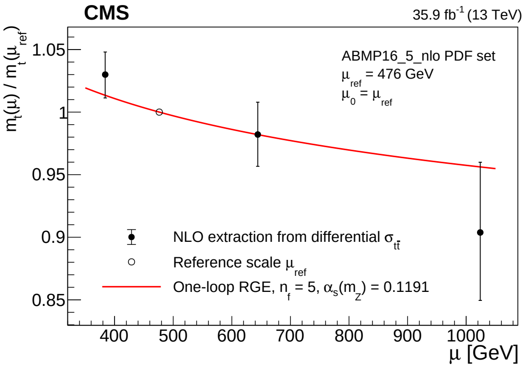
**NEW**

- Running mass equation: $\mu^2 \frac{dm(\mu)}{d\mu^2} = -\gamma(\alpha_S(\mu))m(\mu)$
- 2 opposite flavour leptons final states
- $m_t$ extracted from $d\sigma/dm_{t\bar{t}}$ at parton level

## 4 bins in $m_{t\bar{t}}$

| Bin | $m_{t\bar{t}}$ [GeV] | Fraction [%] | $\mu_k$ [GeV] |
|---|---|---|---|
| 1 | $<420$ | 30 | 384 |
| 2 | 420–550 | 39 | 476 |
| 3 | 550–810 | 24 | 644 |
| 4 | $>810$ | 7 | 1024 |




Phys. Lett. B 803 (2020) 135263

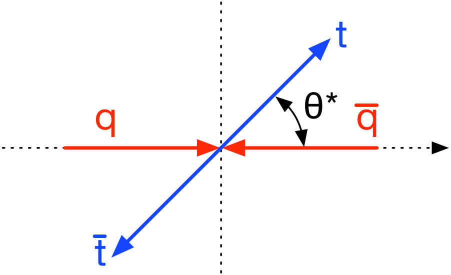
# Forward-backward asymmetry **NEW**

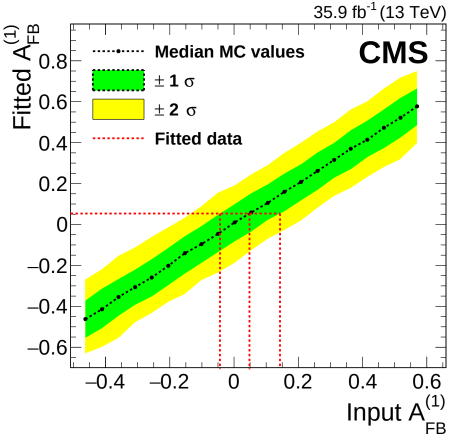
- 1 isolated lepton ($\mu$ or $e$)

arXiv:1912.09540 Submitted to JHEP

- Several variables simultaneously fitted to distinguish between $q\bar{q}$ and gg or qg productions

$$A_{\mathrm{FB}} = \frac{\sigma(\cos\theta^* > 0) - \sigma(\cos\theta^* < 0)}{\sigma(\cos\theta^* > 0) + \sigma(\cos\theta^* < 0)}$$




$$A_{\mathrm{FB}}^{(1)} = 0.048^{+0.095}_{-0.087}\,(\mathrm{stat})^{+0.020}_{-0.029}\,(\mathrm{syst})$$

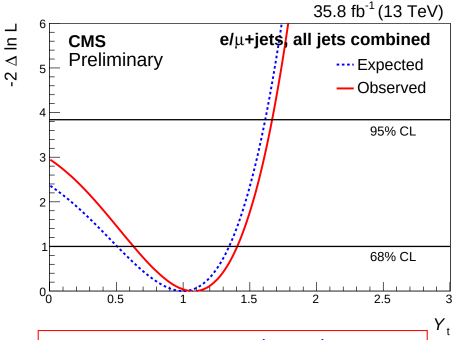
# Yukawa coupling

- Weak force mediated corrections $\sim \mathcal{O}(\alpha^2\alpha_{weak})$
- t and $\bar{\mathrm{t}}$ with small relative velocity, $\sigma_{\mathrm{t\bar{t}}}$ sensitive to Yukawa coupling
- 1 high-pt isolated e/$\mu$, $N_{jets} \geq 3$, $N_{b-tags} \geq 2$
- New kinematic reconstruction technique with one missing jet events
- Missing jet events favour low-$m_{\mathrm{t\bar{t}}}$ region $\rightarrow$ max sensitivity
- Extraction from $m_{\mathrm{t\bar{t}}}$ and $\Delta y = y_{\mathrm{t}} - y_{\bar{\mathrm{t}}}$ for different jet multiplicities.

## Weak virtual corrections


## Exclusion limit

| Channel | Expected 95% CL | Observed 95% CL |
|---|---|---|
| 3 jets | $Y_{\mathrm{t}} < 2.17$ | $Y_{\mathrm{t}} < 2.59$ |
| 4 jets | $Y_{\mathrm{t}} < 1.88$ | $Y_{\mathrm{t}} < 1.77$ |
| 5 jets | $Y_{\mathrm{t}} < 2.03$ | $Y_{\mathrm{t}} < 2.23$ |
| Combined | $Y_{\mathrm{t}} < 1.62$ | $Y_{\mathrm{t}} < 1.67$ |

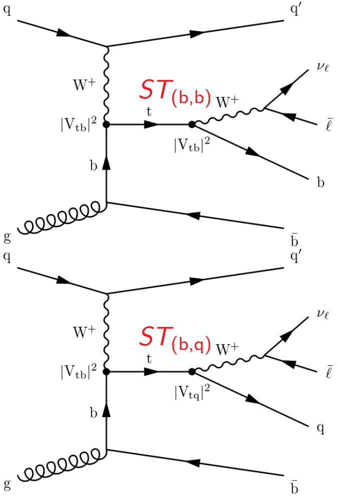



Phys. Rev. D 100 (2019) 072007

# CKM matrix elements

**NEW**

- Single top events indicated for CKM matrix elements measurements
- 1 high-pt isolated e/$\mu$, $N_{jets} \geq 2$, $N_{b-tags} \geq 1$
- several BDTs to discriminate signals $ST_{(b,b)}$ and $ST_{(b,q)}$




**SM assumption**

By assuming: $|V_{tb}|^2 + |V_{td}|^2 + |V_{ts}|^2 = 1$

$$|V_{tb}|^2 > 0.970$$
$$|V_{td}|^2 + |V_{ts}|^2 < 0.057$$

**BSM scenario**

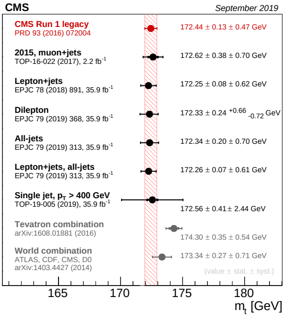
Presence of additional quark families:

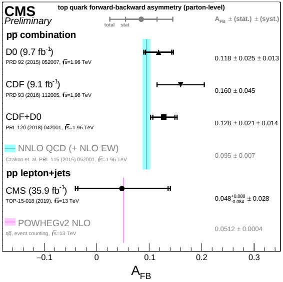
$$|V_{tb}|^2 = 0.988 \pm 0.051$$
$$|V_{td}|^2 + |V_{ts}|^2 = 0.06 \pm 0.06$$

arXiv:2004.12181 Submitted to PLB

# Conclusions

- Many properties of the top quark measured with high precision
- Top mass is one of the most important: direct and indirect measurements with uncertainties below 1 GeV
- Large amount of collision data allows measurements of rare processes to test the SM predictions for the first time:
  - Running top quark mass
  - Direct measurement of $|\mathrm{V_{td}}|^2 + |\mathrm{V_{ts}}|^2$
- Many BSM models can be tested with differential and multi-differential measurements
- No deviation from the SM predictions are observed but the top quark sector is one of the most interesting for BSM physics manifestation



# BACKUP

# Production processes

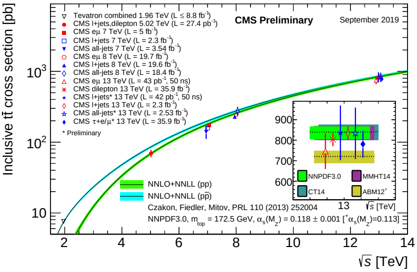
Top quark can be produced by:

## Strong interaction

$t\bar{t}$ pairs

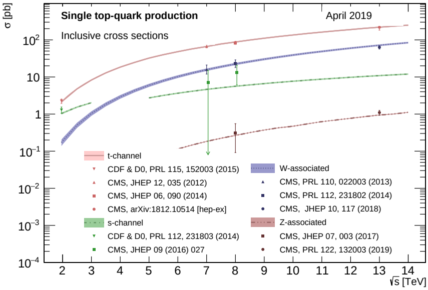
$q\bar{q} \rightarrow t\bar{t}$ (15%) $\quad gg \rightarrow t\bar{t}$ (85%)

$\sigma_{t\bar{t}} = 816^{+19.4+34.4}_{-28.6-34.4}$ pb




## Weak interaction

- *s*-channel
- *t*-channel
- tW associate production
- tZ associate production



# On top mass definition

In the on-shell (o.s.) and $\overline{\mathrm{MS}}$ schemes $S^R(p)$ can then be expressed in terms of pole and $\overline{\mathrm{MS}}$ masses, respectively, as follows:

$$S^R_{\mathrm{o.s.}}(p) \simeq \frac{i}{\not{p} - m_{\mathrm{pole}}} \qquad S^R_{\overline{\mathrm{MS}}}(p,\mu) \simeq \frac{i}{\not{p} - m_{\overline{\mathrm{MS}}}(\mu) - (A-B)m_{\overline{\mathrm{MS}}}(\mu)}$$

The relation between top-quark pole ($m_{\mathrm{t}}^{\mathrm{pole}}$) and $\overline{\mathrm{MS}}$ ($m_{\mathrm{t}}(m_{\mathrm{t}})$) masses was calculated up to four loops in and reads:

$$\begin{aligned} m_{t,\mathrm{pole}} &= \bar{m}_t(\bar{m}_t)\left[1 + 0.4244\,\alpha_S + 0.8345\,\alpha_S^2 + 2.375\,\alpha_S^3 + (8.615 \pm 0.017)\,\alpha_S^4 + \mathcal{O}(\alpha_S^5)\right] \\ &= [163.508 + 7.529 + 1.606 + 0.496 + (0.195 \pm 0.0004)]\ \mathrm{GeV}. \end{aligned}$$

For further details see arXiv:1903.06574v2

# Ideogram method

- PDFs from samples with 7 different mt and 5 different JSF values
- Method bias estimated with pseudo-experiments and corrected

$$\mathcal{L}\left(\text{sample}|m_{\mathrm{t}},\text{JSF}\right) = P(\text{JSF}) \prod_{\text{events}} \left( \sum_{i=1}^{n} P_{\text{gof}}\left(i\right) \times \left[ \sum_{j} f_j \, P_j(m_{\mathrm{t},i}^{\text{fit}}|m_{\mathrm{t}},\text{JSF}) \, P_j(m_{\mathrm{W},i}^{\text{reco}}|m_{\mathrm{t}},\text{JSF}) \right] \right)^{w_{\text{evt}}},$$

where:

- i=i-th permutation in one event
- j=correct permutation, uncorrect permutation, unmatched

Eur. Phys. J. C 78 (2018) 891

# Direct top mass in $\ell$+jets final state details

- Main systematic uncertainty: JEC 0.18 GeV (experimental) JEC 0.32 GeV (model)

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| | 2D approach | | 1D approach | Hybrid | |
|---|---|---|---|---|---|
| | $\delta m_t^{2D}$ [GeV] | $\delta JSF^{2D}$ [%] | $\delta m_t^{1D}$ [GeV] | $\delta m_t^{hyb}$ [GeV] | $\delta JSF^{hyb}$ [%] |
| *Experimental uncertainties* | | | | | |
| Method calibration | 0.05 | <0.1 | 0.05 | 0.05 | <0.1 |
| JEC (quad. sum) | 0.13 | 0.2 | 0.83 | 0.18 | 0.3 |
| – InterCalibration | (−0.02) | (<0.1) | (+0.16) | (+0.04) | (<0.1) |
| – MPFInSitu | (−0.01) | (<0.1) | (+0.23) | (+0.07) | (<0.1) |
| – Uncorrelated | (−0.13) | (+0.2) | (+0.78) | (+0.16) | (+0.3) |
| Jet energy resolution | −0.08 | +0.1 | +0.04 | −0.04 | +0.1 |
| b tagging | +0.03 | <0.1 | +0.01 | +0.03 | <0.1 |
| Pileup | −0.08 | +0.1 | +0.02 | −0.05 | +0.1 |
| Non-$t\bar{t}$ background | +0.04 | −0.1 | −0.02 | +0.02 | −0.1 |
| *Modeling uncertainties* | | | | | |
| JEC Flavor (linear sum) | 0.42 | 0.1 | 0.31 | 0.39 | <0.1 |
| – light quarks (uds) | (+0.10) | (−0.1) | (−0.01) | (+0.06) | (−0.1) |
| – charm | (+0.02) | (<0.1) | (−0.01) | (+0.01) | (<0.1) |
| – bottom | (−0.32) | (<0.1) | (−0.31) | (−0.32) | (<0.1) |
| – gluon | (−0.22) | (+0.3) | (+0.02) | (−0.15) | (+0.2) |
| b jet modeling (quad. sum) | 0.13 | 0.1 | 0.09 | 0.12 | <0.1 |
| – b frag. Bowler–Lund | (−0.07) | (+0.1) | (−0.01) | (−0.05) | (<0.1) |
| – b frag. Peterson | (+0.04) | (<0.1) | (+0.05) | (+0.04) | (<0.1) |
| – semileptonic B decays | (+0.11) | (<0.1) | (+0.08) | (+0.10) | (<0.1) |
| PDF | 0.02 | <0.1 | 0.02 | 0.02 | <0.1 |
| Ren. and fact. scales | 0.02 | 0.1 | 0.02 | 0.01 | <0.1 |
| ME/PS matching | −0.08 | +0.1 | +0.03 | −0.05 | +0.1 |
| ME generator | +0.19 ± 0.14 | +0.1 | +0.29 ± 0.08 | +0.22 ± 0.11 | +0.1 |
| ISR PS scale | +0.07 ± 0.09 | +0.1 | +0.10 ± 0.05 | +0.06 ± 0.07 | <0.1 |
| FSR PS scale | +0.24 ± 0.06 | −0.4 | −0.22 ± 0.04 | +0.13 ± 0.05 | −0.3 |
| Top quark $p_T$ | +0.02 | −0.1 | −0.06 | −0.01 | −0.1 |
| Underlying event | −0.10 ± 0.08 | +0.1 | +0.01 ± 0.05 | −0.07 ± 0.07 | +0.1 |
| Early resonance decays | −0.22 ± 0.09 | +0.8 | +0.42 ± 0.05 | −0.03 ± 0.07 | +0.5 |
| Color reconnection | +0.34 ± 0.09 | −0.1 | +0.23 ± 0.06 | +0.31 ± 0.08 | −0.1 |
| **Total systematic** | **0.72** | **1.0** | **1.09** | **0.62** | **0.8** |
| Statistical (expected) | 0.09 | 0.1 | 0.06 | 0.08 | 0.1 |
| **Total (expected)** | **0.72** | **1.0** | **1.09** | **0.62** | **0.8** |

# Direct top mass in all-had final state details

| | 2D | | 1D | hybrid | |
|---|---|---|---|---|---|
| | $\delta m_t^{2D}$ [GeV] | $\delta$JSF$^{2D}$ [%] | $\delta m_t^{1D}$ [GeV] | $\delta m_t^{hyb}$ [GeV] | $\delta$JSF$^{hyb}$ [%] |
| *Experimental uncertainties* | | | | | |
| Method calibration | 0.03 | 0.0 | 0.03 | 0.03 | 0.0 |
| JEC (quad. sum) | 0.12 | 0.2 | 0.82 | 0.17 | 0.3 |
| – Intercalibration | −0.01 | 0.0 | +0.16 | +0.04 | +0.1 |
| – MPFInSitu | −0.01 | 0.0 | +0.23 | +0.07 | +0.1 |
| – Uncorrelated | −0.12 | −0.2 | +0.77 | +0.15 | +0.3 |
| Jet energy resolution | −0.18 | +0.3 | +0.09 | −0.10 | +0.2 |
| b tagging | 0.03 | 0.0 | 0.01 | 0.02 | 0.0 |
| Pileup | −0.07 | +0.1 | +0.02 | −0.05 | +0.1 |
| All-jets background | 0.01 | 0.0 | 0.00 | 0.01 | 0.0 |
| All-jets trigger | +0.01 | 0.0 | 0.00 | +0.01 | 0.0 |
| $\ell$+jets Background | −0.02 | 0.0 | +0.01 | −0.01 | 0.0 |
| $\ell$+jets Trigger | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 |
| Lepton isolation | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 |
| Lepton identification | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 |
| *Modeling uncertainties* | | | | | |
| JEC flavor (linear sum) | −0.39 | +0.1 | −0.31 | −0.37 | +0.1 |
| – light quarks (uds) | +0.11 | −0.1 | −0.01 | +0.07 | −0.1 |
| – charm | +0.03 | 0.0 | −0.01 | +0.02 | 0.0 |
| – bottom | −0.31 | 0.0 | −0.31 | −0.31 | 0.0 |
| – gluon | −0.22 | +0.3 | +0.02 | −0.15 | +0.2 |
| b jet modeling (quad. sum) | 0.08 | 0.1 | 0.04 | 0.06 | 0.1 |
| – b frag. Bowler–Lund | −0.06 | +0.1 | −0.01 | −0.05 | 0.0 |
| – b frag. Peterson | −0.03 | 0.0 | 0.00 | −0.02 | 0.0 |
| – semileptonic b hadron decays | −0.04 | 0.0 | −0.04 | −0.04 | 0.0 |
| PDF | 0.01 | 0.0 | 0.01 | 0.01 | 0.0 |
| Ren. and fact. scales | 0.01 | 0.0 | 0.02 | 0.01 | 0.0 |
| ME/PS matching | −0.10 ± 0.08 | +0.1 | +0.02 ± 0.05 | +0.07 ± 0.07 | +0.1 |
| ME generator | +0.16 ± 0.21 | +0.2 | +0.32 ± 0.13 | +0.21 ± 0.18 | +0.1 |
| ISR PS scale | +0.07 ± 0.08 | +0.1 | +0.10 ± 0.05 | +0.07 ± 0.07 | 0.1 |
| FSR PS scale | +0.23 ± 0.07 | −0.4 | −0.19 ± 0.04 | +0.12 ± 0.06 | −0.3 |
| Top quark $p_T$ | +0.01 | −0.1 | −0.06 | −0.01 | −0.1 |
| Underlying event | −0.06 ± 0.07 | +0.1 | +0.00 ± 0.05 | −0.04 ± 0.06 | +0.1 |
| Early resonance decays | −0.20 ± 0.08 | +0.7 | +0.42 ± 0.05 | −0.01 ± 0.07 | +0.5 |
| CR modeling (max. shift) | +0.37 ± 0.09 | −0.2 | +0.22 ± 0.06 | +0.33 ± 0.07 | −0.1 |
| – "gluon move" (ERD on) | +0.37 ± 0.09 | −0.2 | +0.22 ± 0.06 | +0.33 ± 0.07 | −0.1 |
| – "QCD inspired" (ERD on) | −0.11 ± 0.09 | −0.1 | −0.21 ± 0.06 | −0.14 ± 0.07 | −0.1 |
| Total systematic | 0.71 | 1.0 | 1.07 | 0.61 | 0.7 |
| Statistical (expected) | 0.08 | 0.1 | 0.05 | 0.07 | 0.1 |
| Total (expected) | 0.72 | 1.0 | 1.08 | 0.61 | 0.7 |

| | $\delta m_t^{hyb}$ [GeV] | | |
|---|---|---|---|
| | all-jets | $\ell$+jets | combination |
| *Experimental uncertainties* | | | |
| Method calibration | 0.06 | 0.05 | 0.03 |
| JEC (quad. sum) | 0.15 | 0.18 | 0.17 |
| – Intercalibration | −0.04 | +0.04 | +0.04 |
| – MPFInSitu | +0.08 | +0.07 | +0.07 |
| – Uncorrelated | +0.12 | +0.16 | +0.15 |
| Jet energy resolution | −0.04 | −0.12 | −0.10 |
| b tagging | 0.02 | 0.03 | 0.02 |
| Pileup | −0.04 | −0.05 | −0.05 |
| All-jets background | 0.07 | – | 0.01 |
| All-jets trigger | +0.02 | – | +0.01 |
| $\ell$+jets background | – | +0.02 | −0.01 |
| *Modeling uncertainties* | | | |
| JEC flavor (linear sum) | −0.34 | −0.39 | −0.37 |
| – light quarks (uds) | +0.07 | +0.06 | +0.07 |
| – charm | +0.02 | +0.01 | +0.02 |
| – bottom | −0.29 | −0.32 | −0.31 |
| – gluon | −0.13 | −0.15 | −0.15 |
| b jet modeling (quad. sum) | 0.09 | 0.12 | 0.06 |
| – b frag. Bowler–Lund | −0.07 | −0.05 | −0.05 |
| – b frag. Peterson | −0.05 | +0.04 | −0.02 |
| – semileptonic b hadron decays | −0.03 | +0.10 | −0.04 |
| PDF | 0.01 | 0.02 | 0.01 |
| Ren. and fact. scales | 0.04 | 0.01 | 0.01 |
| ME/PS matching | +0.24 | −0.07 | +0.07 |
| ME generator | – | +0.20 | +0.21 |
| ISR PS scale | +0.14 | +0.07 | +0.07 |
| FSR PS scale | +0.18 | +0.13 | +0.12 |
| Top quark $p_T$ | +0.03 | −0.01 | −0.01 |
| Underlying event | +0.17 | −0.07 | −0.06 |
| Early resonance decays | +0.24 | −0.07 | −0.07 |
| CR modeling (max. shift) | −0.36 | +0.31 | +0.33 |
| – "gluon move" (ERD on) | +0.32 | +0.31 | +0.33 |
| – "QCD inspired" (ERD on) | −0.36 | −0.13 | −0.14 |
| Total systematic | 0.70 | 0.62 | 0.61 |
| Statistical (expected) | 0.20 | 0.08 | 0.07 |
| Total (expected) | 0.72 | 0.63 | 0.61 |